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A novel justice-based linear model for optimal learner group formation in computer-supported collaborative learning environments

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ABSTRACT

The benefits of computer-supported collaborative learning are well established. To apply this learning strategy, at the initial step learners must be assigned to best collaborative groups. It is a crucial task, because group-mates of each student have major impacts on his/her learning during the collaboration period. In the literature, various approaches have been offered to tackle this problem. However, they suffered from failure to meet all the problem requirements and/or non-optimal solutions and/or very long process time. This study discloses how the problem and all of its requirements can be efficaciously formulated through a binary integer programming approach to construct a linear model which is optimally solvable in a reasonable time. The concept of justice in the context of learner group formation is also introduced and we expose how it can be quantified and applied to the model. For the experiments, 35 undergraduate learners experience collaborative learning through an online course forum for a semester. The performance of the new method was evaluated and compared with results obtained from random grouping and two other greedy and heuristic techniques in terms of four indicators: execution time of the group formation task, mean deviation of the achieved solutions from the optimal, mean student satisfaction with the learning experience, and mean learner new acquired knowledge from collaborative learning. Finding revealed that though the new method was not as fast as the heuristic ones, it generated an optimum solution in a reasonably short time. Results also indicated that the learners were more satisfied and performed better when they were grouped via the suggested method.

1. Introduction

Collaboration is the situation of two or more people working together to create or achieve the same thing (Cambridge Dictionaries Online, 2014). It has permeated various disciplines including business, management and finance, publishing, entertainment, health and medicine, sports, arts and so forth. It is a fact that individuals collaborate with one another to share their knowledge, resources and capabilities. In the recent years, education has become one of the most promising areas for collaboration (Hmelo-Silver, Chinn, O'Donnell, & Chan, 2013). Collaborative learning is an instructional strategy whereby students at different performance levels work together in small groups to accomplish a common learning goal (Dillenbourg, 1999). Researchers often apply the terms collaborative learning and cooperative learning interchangeably. However, in the literature they differ from one another. Learning in cooperative groups occurs individually and involves mainly asynchronous group activities. Members in each group split their work, conclude subtasks individually and then combine the partial outputs to form a joint result. Consequently, cooperative learning may transpire without any interaction between the learners. In contrast, collaborative learning takes place in coordinated, synchronous activities in which participants collaboratively construct knowledge by means of negotiation and sharing (Bennett & Dunne, 1992; Chiriac & Granström, 2012; Dillenbourg, 1999; Galton & Williamson, 1992; Hasler, 2011; Scanlon, 2000; Stahl, Koschmann, & Suthers, 2006). Numerous studies reported that collaborative learning is effective in generating positive outcomes not only in terms of academic performance, but also in supporting the psychological and social aspects of learning (Bossert, 1988; Cohen, 1994; Johnson & Johnson, 1989; Johnson, Johnson, & Holubec, 1984; Kessler, Price, & Wortman, 1985; Kreijns, Kirschner, Jochems, & van Buuren, 2007; Marsh, 2010; Peterson & Swing, 1985; Roberts, 2005; So & Brush, 2007; Webb, 1982). The major advantages of collaborative learning over conventional lecture-based learning are as follows:

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- Learners working together represent the most effective form of interaction and actively engage in the learning process instead of passively listening to the teacher and taking notes. Therefore, deeper levels of thinking and learning through group work are provided (Webb, 1982).
- Students in groups receive immediate feedback or questions regarding their ideas from peers without having to wait for long time to take part in a teacher-led discussion in a classroom (Peterson & Swing, 1985).
- Weaker, reticent and unmotivated learners improve their performance when grouped with higher achieving, communicative and motivated learners (Cohen, 1994).
- Stronger students are provided with deeper understanding that derives only from teaching material (Roberts, 2005).
- Learners feel themselves competent and responsible in teaching their peers. This feeling consequently enhances their self-confidence and also boosts their motivation to learn and then teach (Bossert, 1988).
- Working together reduces feelings of anxiety that stem from having to work independently in a competitive classroom (Johnson & Johnson, 1989; Kessler et al., 1985).
- Group learning encourages the students to be aware of and interact with one another, thereby promoting academic and social relationships, and even developing new friendships (Kreijns et al., 2007; So & Brush, 2007).
- Learning groups provide a safe environment for learners to express themselves, explore their ideas and ask their questions without seeking assistance from teacher, fear of failure or criticism in a public classroom. This strategy boosts learner self-esteem (Marsh, 2010).
- Students learn how to challenge ideas, share workload, advocate for their positions without personalizing their statements and resolve conflicts amicably. These skills are definitely useful for real life situations as well (Johnson et al., 1984).

The term Computer-Supported Collaborative Learning (CSCL) was first articulated by O'Malley and Scanlon (1990). It is a vibrant, promising and interdisciplinary field of research focused on how technology can support, facilitate and enhance collaborative learning. Indeed, CSCL represents a convergence of three disciplines including psychology, education, and computer science that have come together to form this new approach to learning. Nowadays, with the increasing advancement, availability and popularity of computer and communication technologies, CSCL has been a warming trend in the area of education that can provide a more efficacious, more convenient and more flexible collaborative learning experience for both learners and instructors. Furthermore, a large number of research indicates the positive impact of technology on collaborative learning (den Exter, Rowe, Boyd, & Lloyd, 2012; Huang, Huang, & Yu, 2011; Larusson & Alterman, 2009; Magnisalis, Demetriadis, & Karakostas, 2011; Mercier, Higgins, & Joyce-Gibbons, 2014; Schneider & Pea, 2013).

The initial stage in CSCL is assigning students to groups. This is called the group formation task. The way in which learners are grouped affects the quantity and quality of peer interactions which is the most important factor to determine the productivity and success of the learning groups (Martin & Paredes, 2004; Webster & Sudweeks, 2006). Hence, proposing an appropriate group formation strategy might lead to well-structured collaborative learning groups and thereby may prevent many problems before they arise (Muehlenbrock, 2006). Owing to the significance of this field of research, the current work aims to contribute in this regard by introducing a novel effective grouping approach.

The rest of paper is organized as follows. In the next section, the concepts of model and modeling are reviewed and their benefits are described. The section also presents different types of models and their applications. Section 3 reports various existing approaches as well as their pros and cons for solving learner group formation problems. Those motivations that drove the current study are also described. In Section 4, a linear mathematical model to create optimal collaborative learning groups is introduced and it is demonstrated how different problem requirements can efficaciously be added to the model. Section 5 is devoted to defining, gauging and applying the concept of justice in the context of student group formation. In Section 6, the effectiveness of the suggested approach is investigated and compared with those obtained from random grouping and two other greedy and heuristic methods. A short discussion regarding the running time of the new method is provided in Section 7. Finally, the paper is concluded with a brief summary and some directions for future research in Section 8.

2. Theoretical background

A model is a simplified representation or abstract description of a system (or process or theory) intended to enhance our ability to understand, predict, and possibly control the behavior of the system (Neelamkavil, 1987). Furthermore, the process of developing a model is termed modeling. Due to the advantages of working with a model, it is often desirable for a system to be replicated by constructing a model. These benefits can be summarized as follows (Turban, McLean, & Wetherbe, 2001):

- Modeling provides a strong ability of analyzing and exploration of the behavior of a system without conducting the actual experiments.
- The time, money and energy cost of creating, testing and using a model is often much lower than the cost of a real experiment.
- A model allows for years of operation to be simulated in a short time.
- If needed, manipulating the model is much simpler than manipulating the actual system.
- Modeling allows for the calculation of risks in particular actions.
- Gathering data from a computer model is much easier than from a real system.

Modeling can be conducted with various degrees of abstraction. Accordingly, the obtained model is categorized into four main groups, including: Physical models, mathematical models, symbolic non-mathematical models and mental models (Neelamkavil, 1987). Fig. 1 exposes all these formats.

Physical models are constructed from tangible and concrete materials. The real system being physically modeled may range from very small (e.g. an atom) to very large ones (e.g. the earth). On the contrary, a mental model is one that people possess in mind about themselves, others, the environment, and the things with which they interact. People create their mental models by means of training, experience, and instruction (Norman, 2002).

Symbolic models are abstract ones in which symbols are substituted for components of a system and their relationships. Non-mathematical symbolic models, as the name implies, utilize non-mathematical symbols to describe a system. According to Neelamkavil (1987), they can be classified into three groups, including:

- *Linguistic models*: Verbal or written descriptions of events, experiences, dreams, scenes, ideology or codes of practice.
- *Graphical models*: Pictures, paintings, drawings and graphs.
- *Schematic models*: Maps, layouts, flowcharts and diagrams.